

N 70 25 57 1

N 70 57 1

NASA CR 804068
T-70-1804068

MARTIAN ENVIRONMENTAL EFFECTS ON SOLAR CELLS
AND SOLAR CELL COVER GLASSES

Contract No. 952582

TTU Report 3101 - 3rd Quarterly

15 April 1970

Prepared by
F. Alton Wade
Principal Investigator

Texas Tech University
Department of Geosciences
Lubbock, Texas 79409



**CASE FILE
COPY**

MARTIAN ENVIRONMENTAL EFFECTS ON SOLAR CELLS
AND SOLAR CELL COVER GLASSES

Contract No.952582

TTU Report 3101- 3rd Quarterly
15 April 1970

Prepared by
F. Alton Wade
Principal Investigator

Texas Tech University
Department of Geosciences
Lubbock, Texas 79409

This work was performed for the Jet Propulsion
Laboratory, California Institute of Technology,
as sponsored by the National Aeronautics and
Space Administration under Contract NAS7-100

Technical Content Statement

This report contains information prepared by Texas Tech University under JPL subcontract. Its content is not necessarily endorsed by the Jet Propulsion Laboratory, California Institute of Technology, or the National Aeronautics and Space Administration.

Abstract

The project includes the subjection of solar cell assemblages to dust storms in wind tunnels where simulated Martian environmental conditions prevail. The electrical performance of the solar cells is determined by tests before and after subjecting the cell assemblages to dust storms. Damage to the cover glasses and cells is assessed by microscopic examinations and measurements. To date eight (8) tests, all at ambient temperatures, have been concluded except for detailed examinations for damage to cover glasses and cell assemblages. Phase II, tests at constant temperatures of 245°K, is in progress.

Summary

Various investigators have suggested that dust storms do occur in the rarefied atmosphere of Mars. Because the possibility does exist, it is necessary that the effects of such storms on the performance of solar cells be determined prior to a soft landing on Mars. During dust storms fine particulate matter could be deposited on the cells and the cover glasses could be abraded. In either case the efficiency of the solar cells would be reduced. In order to determine how extensive the damage and blanketing effect to the cover glasses might be and the resulting reduction in their efficiency a series of experiments under predicted Martian environmental conditions has been specified.

A wind tunnel of the "race track" type was constructed of plastic and was used in tests at ambient temperatures.

A second wind tunnel has been constructed of sheet metal. Heating and cooling elements are provided in order to control the temperature. A series of tests at 245°K is in progress and a second series with temperatures reproducing diurnal variations over test periods of up to three days will be run.

Following each test the total transmission of the solar cell cover glasses is determined and each cover glass is subjected to microscopic examinations to determine the extent of damage. Current voltage curves are made before and after exposure to each test in order to evaluate the effects upon the electrical performance of the solar cells. Cell assemblages are

tested in groups of four with each subgroup having different protective cover glasses, namely, quartz, Corning No. 0211 Microsheet, sapphire and integral.

In all tests to date solar cell assemblages have been coated with a layer of dust which resulted in a critical reduction in the efficiency of the solar cells. This dust adheres to the surface with such tenacity that it is removed with great difficulty. Inspections after cleaning reveal damage to the cover glasses, mostly pitting. Sapphire cover glasses have minimal damage and in most cases no damage at all.

CONTENTS

Introduction	1
Technical Discussion	3
Preliminary Results of Tests	7
References	8
Appendix	
Description of Wind Tunnels	9

Illustrations

Figure 1. Schedule of tests	6
Figure 2, Wind Tunnel	11

Introduction

Most observers of Martian atmospheric phenomena accept the suggestion that the yellow clouds are dust clouds. Because no reasonable alternative suggestions have been offered, we must accept the possibility that dust storms do occur in the Martian atmosphere. The effects of wind driven dust and sand particles on equipment to be landed on the Martian surface must be determined. If such effects are detrimental to the operation of the equipment, changes to eliminate these effects must be incorporated in their design.

At present most items of equipment which are flown in space or landed on an extraterrestrial body receive their power from solar cell assemblages. In space or on the lunar surface there are no dust storms so the problem of their detrimental effect has not existed to date. On Mars the problem may exist and equipment may become inoperative for lack of power following a dust storm.

In order to determine the effect of dust storms on solar cells and solar cell cover glasses a series of tests has been designed in which these objects will be subjected to dust storms at specified wind velocities, temperatures or temperature ranges, in a carbon dioxide atmosphere containing a trace of moisture. These tests will be carried out in wind tunnels designed specifically for them. To assess the results the following tests will be made.

- (i) The total transmission of the solar cell cover glasses before and after subjecting them to dust storms.

- (ii) Microscopy of solar cell cover glasses using phase contrast and polarized light techniques.
- (iii) Current voltage curves will be made before and after exposure to dust storms as is necessary to evaluate the effects upon the electrical performance of the solar cell cover glass combinations.
- (iv) Following (iii) cover glasses will be removed and the measurements repeated.

Technical Discussion

Based upon data presented in JPL Document No.606-1, dated July 15, 1968 (1), the Martian environment at or very near the surface is as follows.

Surface pressure - ~ 10 mb

Composition of the atmosphere - $>50\%$ CO_2 , the remainder probably an inert gas such as argon , plus or minus trace of water vapor.

Temperatures

Maximum at equator - $\sim 305^\circ\text{K}$

Minimum at equator - $\sim 170^\circ\text{K}$

Mean amplitude of diurnal variation at equator - $\sim 96^\circ\text{K}$

Mean polar cap region (estimated)

Winter - $\sim 220^\circ\text{K}$

Summer - $\sim 265^\circ\text{K}$

The surface material is believed to resemble olivine basalt or tholeiitic basalt. The surface layer is probably composed of unsorted particulate basalt which ranges in size from a few microns to blocks measuring tens of centimeters in dimensions.

Wind velocities based upon observed motions of yellow clouds may range up to 100 km per hour.

In the design of the tests to which solar cells and solar cell cover glasses will be subjected some exceptions to the above specifications were made.

Pressure. Because of the extreme difficulty in maintaining a pressure of 10 mb and wind velocities of up to 100 km/hr in a wind tunnel, it was agreed to use ambient pressures. Actually this will result in "worst case" phenomena during tests. Corrected wind velocities can be determined mathematically.

Atmosphere. The atmosphere will be 100% carbon dioxide \pm a trace of water.

Temperature. One series of tests will be run at ambient temperatures, a second series at 245°K and a third with a diurnal variation from 210°K to 305°K.

Wind Velocities. One series of tests will be conducted with wind velocity at 50 km/hr, and a second at 100 km/hr.

Particulate Matter. The dust particles to be used in the tests were obtained by grinding and sieving olivine basalt which was collected in the Hudson Mountains, Ellsworth Land, Antarctica. The principal constituents are clinopyroxene, plagioclase and olivine. A small amount of glass is present. This differs somewhat from the composition of the fines in the lunar soil obtained by the astronauts of Apollo 11. In the lunar material glass constitutes about 50 percent and ilmenite is a principal constituent (2). These compositional differences should not alter the results of the tests significantly. Wind tunnel tests have shown that movement of particles of less than 60 microns in size will not be initiated by wind velocities of 100 km/hr or less. The presence of slightly larger particles is necessary to initiate movement. These larger particles move by the process of saltation and with every bounce finer particles are knocked into the air stream where they remain in suspension. The fines in the lunar soil material brought to earth by the astronauts in the "bulk box" were composed of approximately 45% in the 125-62.5 micron range and 25% in the less than 62.5 micron range (2). Based upon observations of the generation of dust storms in the wind tunnel using various size particles, it was decided that "worst case" conditions could be obtained using a mixture of particulate matter

composed of 75% in the 125-250 micron range and 25% in the <62.5 micron range. These are weight percentages.

The schedule of tests completed and projected is shown in Figure 1.

Tests at ambient temperatures in Tunnel No. 1 (plastic) were begun on January 20, 1970 and completed on March 15, 1970. All other tests will be performed in Tunnel No. 2 (metal).

6

TEMPERATURES																																		
AMBIENT				AVERAGE (245° K)								DIURNAL CYCLE																						
SOLAR CELL PROTECTION				SOLAR CELL PROTECTION								SOLAR CELL PROTECTION																						
Days	Vel. Km	Atmos. CO ₂	Corning #0211 Micro- sheet				Quartz				Sapphire				Integral Glass Covers				Corning #0211 Micro- sheet				Quartz				Sapphire				Integral Glass Covers			
			A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B				
1	50	Wet	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	100	Wet	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
3	50	Wet	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					
	100	Wet	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					

A = Expanded silver mesh
 B = JPL bus bar Dwg #10016709-1
 X = Tests in tunnel completed
 O = Tests to be run

Figure 1. Schedule of Tests

Preliminary Results of Tests

As indicated in Table 1, eight sets of cell assemblages have been subjected to dust storms in Tunnel No. 1 at ambient temperatures. Current-voltage curves were made for each cell assemblage prior to subjection to a dust storm and then again afterwards. A tightly adherent coating of dust collected rather uniformly on each assemblage. After the second set of current-voltage curves was made, the cover glasses were cleaned and a third set of current-voltage curves was produced. From this set can be determined changes in efficiency due either to cover glass damage or connector damage or both.

Computation and reduction of data is in progress and no final results are available. However, preliminary analysis of the data for an assemblage which includes No.'s 2,13,25 and 37 indicates reduction in the current producing efficiency of the cells after a dust storm by 75 to 80%. After cleaning the efficiency of the cells returned to near their original levels. However, in no case was this return complete.

Each cover glass was inspected for imperfections, scratches, etc. prior to dust blasting and again after removing the dust. Damage ranges from greatly pitted surfaces to little or no change. Of the four types of cover glasses sapphire was the least damaged. Connectors were abraded and, in one case, sufficiently to produce a disconnection.

References

1. Mars Scientific Model. JPL Document No.606-1.
July 15, 1968. Prepared by members of the Lunar
and Planetary section.
2. Preliminary Examination of Lunar Samples from
Apollo 11. 1969. Science, Vol. 165, p. 1219.
Prepared by the Lunar Sample Preliminary Examination
Team.

Appendix

Description of Wind Tunnel No. 1.

The wind tunnel for test experiments at ambient temperatures and preliminary tests is constructed mainly of quarter inch plexiglass. It is essentially a closed system shaped like a race track (Figure 2). The 'atmosphere' is circulated with a squirrel cage blower which is driven by an electric motor. Wind velocities in the straight-away sections of the race track where the tests are performed are controlled by varying the cross section.

Three pairs of straight-away sections are available. With one pair a wind velocity of 50 km/hr is maintained; with the second 75 km/hr and 100 km/hr with the third. With this arrangement no variations in blower rpm are necessary to produce the desired velocities. The solar cell modules to be tested are mounted on weighted brackets in such a way that the entire outer face of each cell and the wire connectors are exposed to the dust storms. Before reassembling the race track an adequate amount of 'Martian dust' is distributed in the various sections. Prior to each test the atmosphere in the race track is swept out and replaced with CO₂ gas in which there is a trace of water vapor. The reason for the use of plexiglass in the race track is to make possible direct view of the dust storms. Preliminary tests have shown that some turbulence is generated in the curved sections, but that the flow in the straight sections when the tests are performed is essentially laminar.

Wind Tunnel No. 2.

The second wind tunnel is the same in design as No. 1, but is constructed of metal sheeting, insulated and equipped with cooling and heating devices. The temperature can be controlled. It has the same aerodynamic characteristics as the plexiglass tunnel.

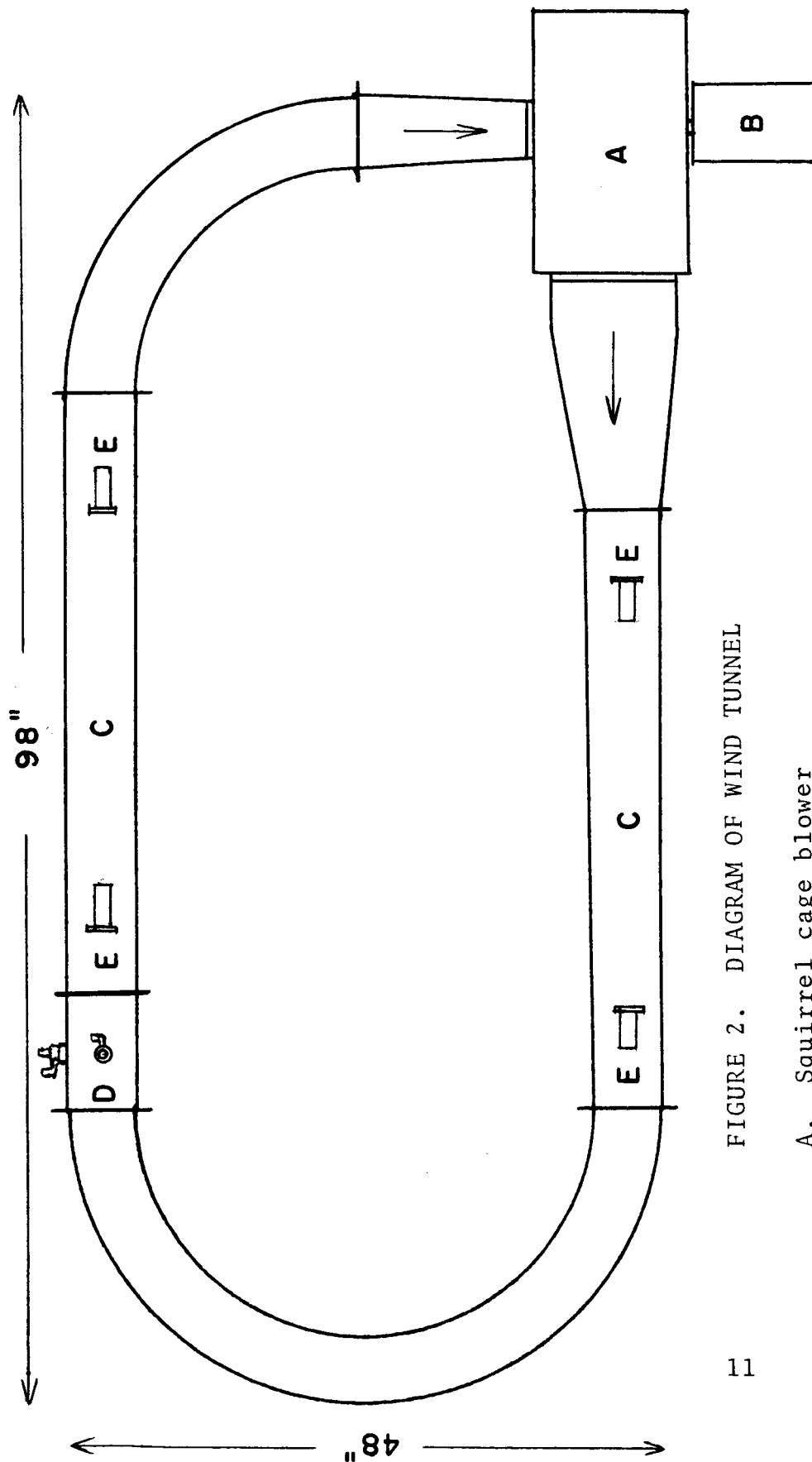


FIGURE 2. DIAGRAM OF WIND TUNNEL

- A. Squirrel cage blower
- B. Motor
- C. Removable straight-away sections
- D. Valve section. CO₂ inlet and outlet
- E. Solar cell assemblies